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ON INFANT FOODS.

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A Lecture delivered by invitation before the College of Physicians of Philadelphia.

BY

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In attempting to discuss the problem of infant foods, I shall begin by assuming that the natural food of the human infant is the best infant food. Without pausing to give the grounds on which it is based, I shall merely add, that the conviction has constantly strengthened with the progress of chemical analyses of human milk and of the various substitutes which have been proposed, that the above assumption is the safest and least presumptuous one which can be made in the present stage of theoretic and practical knowledge.

But what is human milk? To answer this question satisfactorily, we should know at least three things: 1. All the components; 2. Their relative proportion; 3. Their chemical and physiological properties.

Strangely enough, present knowledge on all these points is very far from satisfactory. With reference to the first point, it is sufficient to state that no complete analysis of woman's milk has yet been made. As to the second, I am not referring to the fact that the milk necessarily varies with the interval since parturition, the nutrition and constitution of the mother, and numerous other variable elements, but to the much more important one, that the average composition of the milk of healthy nursing women is by no means satisfactorily established. You will be surprised, I think, on turning to the literature of this subject to find how widely different are the figures obtained by investigators, and variously adopted, usually without critical consideration, in works treating of the nutrition and diseases of children. Finally, in reference to the third point, our knowledge of the properties of the components themselves is extremely meagre. We know,

as yet, very little concerning the true nature of the nitrogenous bodies, which are lumped together under the head of albuminoids. And as to the fat of human milk, no separation into the many oily and fatty bodies, of which it is made up, has as yet been attempted.

It may be said that this is foolish hypercriticism—that if we do not know everything, we know sufficient to conduct the nutrition of infants on a sound basis of adequate knowledge. But many reasons could be given under the heads previously specified for regarding the last assumption as premature. Our time will not permit us even to allude to these, but will enable us to speak only of the one practical issue which it is our business to deal with this evening. This is, granting that woman's milk is the best infants' food, in what manner should the nature and proportions of the components be determined of any substitute we may be necessitated to employ? Certainly, only by knowing, in the first place, the average composition of human milk.

As this point is fundamental, and as the wide diversities I have just alluded to existed concerning it, I have thought it well to devote the past four months to its study. In this labor I have had the cordial co-operation of Dr. A. M. Thomas, Chief of Medical Staff of the Emigrants' Asylum and Hospital, and, during the later part of the inquiry, of Dr. K. Parker, of the Infants' Asylum of New York. Both of them have given their personal attention to the collection of the samples, which, in every case, were taken from healthy women, mainly young and primiparæ. All the points of interest, with regard to the history of the women, the child, and the sample, have been tabulated and coördinated, and will probably be published in connection with a future monograph devoted to the topic of human milk. This would not be a proper place for these details, further than adding that the samples usually amounted to two ounces, were taken in most instances two hours after time of last nursing, and were generally the entire contents of the gland.

The sources of variation in the multitudinous analyses of woman's milk that have been previously

published, are principally three in number—the most important being the differences in the methods of analysis; next, the variations in the constitution of the milk itself; lastly, the circumstances connected with the collection of the sample. Without delaying to discuss these matters, which would require much time and precision of statement, I shall bring before you to-night only so much of the results thus far obtained as are needed for our present purpose. They are to be regarded as an approximation, to be still further modified by incorporation of the results of other analyses still in progress.

Analyses of Forty-three Samples of Woman's Milk.

Reaction uniformly alkaline.

	Average.	Minimum.	Maximum.
Specific gravity, . .	1.0317	1.030	1.0353
Water, . . .	86.766	83.34	89.09
Total solids, . .	13.234	10.91	16.66
Total solids not fat, .	9.221	6.57	12.09
Fat, . . .	4.013	2.11	6.89
Milk-sugar,. .	6.997	5.40	7.92
Albuminoids, . .	2.058	0.85	4.86
Ash, . . .	0.21	0.13	0.35

Not only was the reaction alkaline when the samples were fresh, but, with one exception, in which it was neutral, this alkalinity was found to remain twenty-four or more hours after.

The most striking feature in these analyses is the great range of variation in the amounts of certain constituents, more especially in the albuminoids, the maximum, 4.86 per cent., being nearly six times the minimum, which is only 0.85 per cent. The next most variable constituent is the fat, the maximum being more than three times the minimum. Then come the saline matters, nearly three, and last of all the milk-sugar, which differs but little from the mean (6.997 per cent.) in most samples. In other words, the most striking peculiarity in woman's milk is not the constancy, but the great variability in its composition. Furthermore, this variability is by far the greatest in

the constituent most essential to nutrition, the albuminoids, and diminishes in degree of variability in proportion as the constituent becomes less and less essential to nutrition, becoming very nearly constant in the case of milk-sugar, the function of which is not nutrition but heating; by which nature appears to intend to teach us that the rate of nutrition in an infant may safely vary within wide limits, but that the animal heat of an highly organized and rapidly developing creature must be maintained *coûte qu'il coûte.* To maintain at a temperature somewhat exceeding that of an adult, a creature whose vital processes on the one hand are of great activity, while on the other hand the supplies of heat due to cerebral impulses and self-originating locomotions are extremely small, requires the rapid consumption of available fuel, and the abundance of carbohydrates in the milk supplies this most imperative want.

Without stopping to draw out the significance contained in the proportionality of the constituents, both as considered in themselves and as compared with the new-born of other mammalia, let us hasten on to the comparison of human milk with its nearest analogue. This is properly asses' milk, but as this is not and never will be generally available, it will be more profitable for us to consider the cheap and universally accessible cow's milk. For a similar reason, I shall not institute a comparison between the above average and that of the rich milk of blooded cattle, the Alderneys, Jerseys, and so on, nor with selected samples from the best ordinary milch-cows. Rather, as such comparison will be of greater practical utility, I shall adduce the analyses of unadulterated whole commercial or "market" milk. And as this market milk is itself the average of a great number of samples, it is useless, so far as it is concerned, to give the maxima and minima of its individual constituents.

As determined by methods identical with those employed in the analyses of woman's milk, I shall state, therefore, the following results, obtained upon samples of unadulterated cow's milk, such as is sold by farmers

in New Jersey to the citizens of New York and Philadelphia.

Analyses of Eleven Samples of Whole Market Milk.

Water,	87.7	per cent.
Total solids,	12.3	"
Total solids not fat,	8.48	"
Fat,	3.75	"
Milk-sugar,	4.42	"
Albuminoids,	3.42	"
Ash,	0 64	"

As in the case of woman's milk, the slight discrepancies noticeable are due to the fact that the figures for "total solids" were those obtained by appropriate separate determinations, and of course do not precisely agree with the figures obtained by mere addition of the solid constituents.

Before proceeding to make a comparison, I wish to quote here the results given by König (*Chemie der mensch. Nahrungs- und Genussmittel*), deduced in each case from the analyses of many hundred samples of woman's and cow's milk, and to call attention to the fact that whilst these results include determinations effected by very many and diverse methods of all descriptions of samples, and present a distinction between caseine and albumen (a distinction which cannot be sharply effected by present analytical methods), yet as a whole they are similar to and support the inductions which I shall base upon the analyses above given.

Woman's Milk.

	Mean.	Minimum.	Maximum.
Water,	87.09	83.69	90.90
Total solids,	12.91	9.10	16.31
Fat,	3.90	1.71	7.60
Milk-sugar,	6.04	4.11	7.80
Caseine,	0.63	0.18	1.90
Albumen,	1.31	0.39	2.35
Albuminoids,	1.94	0.57	4.25
Ash,	0.49	0.14	?

Cow's Milk.

	Mean.	Minimum.	Maximum.
Water,	87.41	80.32	91.50
Total solids,	12.59	8.50	19.68
Fat,	3.66	1.15	7.09
Milk-sugar,	4.92	3.20	5.67
Caseine,	3.01	1.17	7.40
Albumen,	0.75	0.21	5.04
Albuminoids,	3.76	1.38	12.44
Ash,	0.70	0.50	0.87

The same striking peculiarities are noticeable in the above analyses of woman's milk. The greatest variable is the albuminoid constituent, the maximum being more than seven times the minimum; the most nearly constant is the milk-sugar, varying little from the mean of 6.04 per cent., which is likewise the largest of the solid constituents.

When we compare woman's with cow's milk, it is the great differences and not the similarities which surprise us, and demand study, recognition, and utilization in the solution of the problem of artificial infant's food. In woman's milk we have a persistently alkaline liquid, of a somewhat animal, usually disagreeable, and very rarely sweetish taste, of somewhat greater specific gravity (1.0317) than cow's milk (1.029). Although it has less water, and greater total solids, and total solids not fat, than cow's milk, it is by no means so opaque, and with its thin and watery consistence gives us a notion the reverse of true with regard to its real composition. Agreeing with cow's milk in the fact that the milk-sugar in both is the chief solid, it differs in that its milk-sugar largely exceeds the milk-sugar of cow's milk. It likewise exceeds in fat. In albuminoids it falls far below. And whilst by present modes of analysis the separation of the so-called caseine from the so-called albumen is not accurately performed, yet the results are approximately correct, and have a very great value in pointing out the most important of all the differences between the two secretions, which is that the fraction of the total albuminoids in cow's milk which is coagulable by acids is far greater (perhaps four times) than the non-coagulable part.

In woman's milk, on the contrary, the reverse is true, and the non-coagulable part much exceeds (perhaps by more than twice) the coagulable portion. And whilst the absolute amount of ash is less, the relative amount of potash is greater, in woman's than in cow's milk.

For reasons which will appear further on, it would seem that the best solution of the problem of artificial infant feeding is to be found in the substitution of cow for human milk. But, inasmuch as the secretion of the herbivora is radically and in all particulars different from that of the omnivora, cow's milk is profoundly altered, so as to assimilate, in the ratio and nature of its constituents, human milk.

To discuss the various methods by which it has been proposed to effect this result would far outrun my present scope, which is only so much of the general discussion as relates to the influence exerted upon cow's milk by the addition of the various articles of infant food now manufactured and offered for sale. This influence, we shall find, is chiefly of a mechanical or physical character, and does not necessarily involve the discussion of those chemical changes, at present time under investigation in many quarters, the practical results of which have not yet been satisfactorily determined, and belong, therefore, to the future of this subject.

The method hitherto employed is spoken of as mechanical for reasons based partly on the practice of physicians and partly on laboratory experiments. The mere addition of water to cow's milk is sufficient to reduce the percentage of albuminoids to the same amount as its percentage in human milk. But this addition does little to diminish the size and compact character of the clot of cow's milk. This last is effected, as far as it actually is effected, which is only partially, by the addition of the various attenuants composing manufactured infant's food, whether that attenuant is starch, gum, sugar, dextrine, or other bland nutrient. This explanation of the utility of manufactured infant's foods accounts for the seeming anomalies in present medical practice, which at first sight appear very start-

ling and inconsistent with generally accepted physiological doctrines. For whilst admitting that the secretions of the salivary and pancreatic glands are insufficient in the early stages of infancy to digest more than very limited amounts of starch, yet physicians frequently use with good results a farinaceous food like Ridge's, which contains 77.96 per cent. of starch, or like Robinson's patent barley, which contains 77.76 per cent. of starch. But when we consider that the utility of this starch is not in the way of infant's food, for which it is not adapted, but as an attenuant of the large amount of diluted milk with which it is mixed, then the seeming contradiction between theory and practice disappears.

To discover whether this interpretation is in accord with experiment, the coagulation was effected in the presence of similar attenuants. In the first place, the total albuminoids were determined in a sample of whole cow's milk, and were found to be 3.39 per cent. The so-called caseine was then separated by coagulation with acetic acid, and amounted to 2.42 per cent. On boiling the filtrate, 0.26 per cent. of albumen so called separated out, leaving a deficiency of 0.71 per cent. of albuminoids to be accounted for. A direct determination of the albuminoids in the filtrate from the albumen, gave an additional yield of 0.76 per cent., showing that both coagulation and boiling of the filtrate subsequently had left nearly one-fourth of the total albuminoids in solution.

Ten grammes of the same milk, together with 25 grammes of cane-sugar and 110 c.c. of water, were treated in like manner, the precipitates being exhaustively washed. I obtained:

As precipitated by acid,	3.13	per cent.
" " by boiling,	0.40	"
Precipitated by copper sulphate from filtrate,	1.14	"
	4.67	"
Total albuminoids,	3.39	"
	1.28	"

In other words, the precipitates carried down with them 1.28 per cent. of saccharine matter, which could not be removed by washing.

Some barley-water was then made and filtered through ordinary Swedish filter paper, the clear filtrate being used in the following experiment. Ten grammes of the same milk as before were mixed with 110 c. c. of the barley-water. I obtained:

As precipitated by acid, ...	5.21	per cent.
" " by boiling, ...	0.37	"
" " by copper sulphate from filtrate, .	1.35	"
	6.93	"

That is to say, the precipitates carried down with them from the clear barley-water 3.54 per cent. of barley extract, which could not be removed by washing. In this case, the attenuants of the clot exceeded in weight the coagula themselves.

An experiment with grape-sugar yielded results closely resembling those with cane. With gelatine a very remarkable result was obtained. Ten grammes of the same milk were added to 110 c.c. of a solution of 1 part of gelatine in 150 parts of water. Although the gelatine was so attenuated, it entirely prevented the precipitation of caseine on the addition of acid, and what is likewise interesting, appeared to arrest decomposition, the white jelly not having altered after a week's standing.

Ten grammes of the same milk were added to 110 c.c. of clear starch-water (filtered through Swedish filter paper). I obtained:

As precipitated by acid, ...	3.07	per cent.
" " by boiling, ...	0.36	"
" " by copper sulphate in the filtrate,	1.08	"
	4.51	"

Or 1.12 per cent of starch carried down and not separable by exhaustive washing.

The utility of diluting cow's milk until its percentage of albuminoids does not exceed that of human milk,

and adding some bland attenuant, is obvious. But the special virtues of the *extractive* of barley or oatmeal, as compared with starch, and the relative value as nutrients of sugar, gum, dextrine, gelatine, barley, oatmeal, etc., and their relative advantages when thus employed, have been very imperfectly determined. It is much to be desired that new physiological and chemical experiments directed especially to these all-important factors in infant nutrition should be instituted. I shall have occasion to refer to the same points in connection with Liebig's Foods.

An examination of the great variety of infant foods, the analyses of which are given in the following pages, shows that they can be classified most conveniently under the three heads of Farinaceous, Liebig's Foods, and Milk Foods (including condensed and preserved milk).

I. *Farinaceous.*

A.—Wheat, previously prepared by baking, including:

1. Blair's Prepared Wheat Food; 2. Hubbell's Prepared Wheat Food; 3. Imperial Granum; 4. Ridge's Food.

B.—Mixtures of various cereals:

5. "A B C" Cereal Cream; 6. "A B C" Cereal Milk; 7. Robinson's Patent Barley.

II. *Liebig's Foods.*

8. Mellin's; 9. Hawley's; 10. Horlick's; 11. Keasbey and Mattison's; 12. Savory and Moore's; 13. Baby Sup No. 1; 14. Baby Sup No. 2.

III. *Milk Foods.*

15. Nestlé's; 16. Anglo-Swiss; 17. American-Swiss; 18. Gerber's.

Class I.—A.

	1. Blair's wheat food.	2. Hubbell's wheat food.	3. Imperial granum.	4. Ridge's food.
Water, ...	9.85	7.78	5.49	9.23
Fat, ...	1.56	0.41	1.01	0.63
Grape-sugar, .	1.75	7.56	trace	2.40
Cane-sugar, . .	1.71	4.87	trace	2.20
Starch, ...	64.80	67.60	78.93	77.96
Soluble carbohydrates,	13.69	14.29	3.56	5.19
Albuminoids, . .	7.16	10.13	10.51	9.24
Gum, cellulose, etc. .	2.94	undeterm'd	0.50	
Ash, ...	1.06	1.00	1.16	0.60

1. *Blair's Wheat Food.*—It is claimed that this is prepared from choice wheat in such a manner as to retain all the nutritive constituents and reject those which are irritating or otherwise objectionable. Moreover, that by cooking such physical and chemical changes have been brought about as to facilitate mastication and the subsequent action of the fluids of the stomach, thereby rendering the food more easily digested. It is stated to be especially beneficial in intestinal diseases like dysentery, cholera infantum, etc.

Uncooked, this flour has a sweet pleasant taste. When cooked according to directions it forms a very smooth paste with a faint tinge of color, resembling arrowroot in its flavor and quite palatable without the addition of salt, sugar, milk, or other accompaniments.

2. *Hubbell's Wheat Flour.*—Claimed to be made from wheat alone, floured and carefully baked from eight to ten hours, at about the temperature of boiling water. "It includes all the flesh-forming constituents, earthy and saline elements of the grain, with only a portion of the starch, and of the silicated coating. It keeps without change."

This flour is quite sweet and palatable even in its uncooked form, and when moistened with the saliva is more pasty than the Blair's wheat flour. When cooked it forms a perfectly white, smooth paste, with a very delicate flavor. It is more starch-like in consistency than Blair's, a difference due in part to the larger per-

centage of starch, and less pronounced in flavor, this being probably due in some degree to the smaller percentage of fat. In both Blair's and Hubbell's the per cent. of gum, cellulose, etc., is extremely small, in the latter so small that it was not determined. In nitrogen Hubbell's is much richer than either of the other two preparations, and its value for purposes of nutrition correspondingly greater. The reaction of Blair's food and of Hubbell's is in each neutral.

The excess in the amount of saccharine matter in Hubbell's food above that contained in ordinary wheat flour induced me to write for particulars of the change which it had undergone. The process, I was informed, is as follows: A large baker's oven is heated to about 340° to 360° F. The flour, contained in shallow Russia iron pans, is then put in, the fire having meantime been withdrawn, the oven closed, and the flour left there about twenty-four hours. When the oven is reopened the temperature will have fallen to 100°, and after sieving, the prepared flour will be ready for use. The flour used is the best grade as made by the roller process, the second grade containing more starch, less gluten, being that bought and used by bakers.

The two following analyses, the first of Hubbell's prepared wheat flour, the second of the flour from which the first was obtained by the process of baking as conducted in the manner above described, are interesting and important as elucidating the nature of the changes thus induced.

	Wheat flour.	Same baked.
Water,	9.02	7.78
Fat,	1.01	0.41
Grape-sugar,	2.34	7.56
Cane-sugar,	2.46	4.87[1]
Starch,	76.07	67.60
Soluble carbohydrates,	5.66	14.29
Albuminoids,	7.47	10.13

It will be seen that the flour has lost moisture in baking, and also a portion of its fat. These changes, however, are of little moment compared with the con-

[1] With some dextrine.

siderable decrease of starch and its conversion into saccharine bodies. The soluble carbohydrates are considerably more than doubled, and this change is one of the greatest value and importance, so far as the dietetic value of the prepared food is concerned. The considerable increase in the percentage of albuminoids I am unable to account for.

3. *Imperial Granum.*—It is stated to be "in composition principally the gluten derived by chemical process from very superior growths of wheat—a solid extract." Dr. Fowler states (*Amer. Journ. Obstetrics*, April, 1882), as the result of his microscopical examination, that if the material from which this preparation is derived contains any gluten at all, the "chemical process" resorted to in order to extract it has at the same time either destroyed it, or so altered its character as to render it no longer recognizable by the usual tests. This is an excellent illustration of the difficulty which is encountered in deciding with the microscope upon the constitution of a cereal after treatment, for whilst Dr. Fowler's statement of the microscopic appearance is in accordance with my own observations, yet as a matter of fact the imperial granum contains 10.51 per cent. of albuminoids. On the other hand this is not sufficient by any means to bear out the statement that the imperial granum consists principally of gluten. According to Dr. Fowler, it is simply coarse barley flour. My own observations make it a wheaten preparation.

4. *Ridge's Food.*—It is advertised as "prepared from carefully selected winter wheat," reduced to an almost uniform fineness. The product is then thoroughly cooked by a steam-baking process, which gradually changes a large proportion of the starch into dextrine, excluding only the woody fibre. It is afterwards rendered a little sweet and slightly alkaline.

Dr. Fowler states (*loc. cit.*) that the Ridge's food is apparently barley flour finely ground, and that the odor, dough, and microscopic appearance indicate no other ingredients. I have placed it, in accordance with my own observations, among the wheat preparations. Both Imperial Granum and Ridge's food when

cooked are very palatable. Both have a neutral reaction. Both have a considerable percentage of albuminoids, that of Imperial Granum in the two samples analyzed being the higher, and both have a very high percentage of starch.

It should be very carefully borne in mind that wheat flour after carefully baking is extensively altered, and that the albuminous bodies become considerably more soluble in water. A wheat flour, which in its original condition would yield after baking a very considerable amount of crude gluten on washing, after baking will leave a much smaller quantity, and for this reason the percentage of crude gluten in baked flours cannot be roughly estimated by washing and drying. For the same reason a baked wheat flour may be mistaken for barley flour, which gives a non-glutinous dough.

Class I.—B. *Mixture of Various Cereals.*

	6. "A B C" Cereal Milk.	7. Robinson's Patent Barley.
Moisture,	9.33	10.10
Fat,	1.01	0.97
Grape-sugar,	4.60	3.08
Cane-sugar,	15.40	0.90
Starch,	58.42	77.76
Soluble carbohydrates,	20.00	4.11
Albuminoids,	11.08	5.13
Cellulose, gum, etc.,	1.16	1.93
Ash,	......	1.93

5. "*A B C*" *Cereal Cream.*—Stated to be "prepared from the most nutritious and digestible parts of the choicest wheat and barley, with all impurities removed." It appears to be a coarse meal of wheat and barley, but I did not analyze it, the box which I purchased being probably old and its contents spoiled.

6. "*A B C*" *Cereal Milk.*—"Prepared by a scientific admixture of the nitrates and phosphates of wheat with the whole barley; and after adding the required sugar, we have secured an analysis almost identical with human milk. The wheat is first cleansed, then hulled, coarsely ground, and the surplus starch removed, leaving the nitrates and phosphates. The barley is hulled,

crushed, and mixed with a proper proportion of the wheat nitrates and phosphates. The mixture is cooked by steam, desiccated, ground into fine flour, specks bolted out, and the requisite amount of sugar added."

The statement that this food corresponds nearly with human milk in its nutritive ingredients is untrue. The proportion between its various constituents is entirely unlike that in human milk, and more than half consists of starch, a body entirely foreign to milk.

7. *Robinson's Patent Barley.*—"Patent barley, technically, is ground pearl barley. Yet this preparation, while possessing most of the characters of what it purports to be, is somewhat unlike pure barley flour. Its dough is more adhesive, and the white color, together with the mild barley odor, suggest the admixture of wheat flour. No gluten cells are seen, but there are numerous granules unaffected by iodine, and turned red by carmine (albuminous matter). The microscopic examination shows starch granules free and in bundles, held together by the cellulose. The larger corpuscles are probably those of wheat." I have adopted this description of Dr. Fowler, although I am inclined from my own observations to regard the preparation as merely barley flour.

The first three are dried foods, in brown or granular masses, and very sweet; the Mellin's food looking and tasting very much like pulverized candy. Their aqueous solutions besides this sweet, had an after-taste of alkaline salt. Under the microscope Horlick's food exhibited very few starch granules, some cellulose, hairs of wheat, but mostly dark bundles of entirely unrecognizable granular matters, probably converted starch. Mellin's food goes almost entirely into solution, and I failed to recognize under the microscope the minute irregular granular matter left behind. The materials sent to me by the manufacturers of Horlick's food, as representing their regular consumption, consisted of fine white wheat flour not baked, good barley malt, and pure bicarbonates of soda and potash. Singularly enough, the reaction of the Horlick food analyzed was acid; that of the Hawley's food was acid likewise, while the Mellin's food was alkaline.

Class II.—Liebig's Foods.

	8. Mellin's.	9. Hawley's.	10. Horlick's.	11. Keasbey and Mattison's.	12. Savory and Moore's.	13. Baby Sup No. 1.	14. Baby Sup No. 2.
Water,	5.00	6.60	3.39	27.95	8.34	5.54	11.48
Fat,	0.15	0.61	0.08	None.	0.40	1.28	0.62
Grape-sugar,	44.69	40.57	34.99	36 75	20.41	2.20	2.44
Cane-sugar,[1]	3.51	3.44	12.45	7.58	9.08	11.70	2.48
Starch,	None.	10.97	None.	None.	36.36	61.99	51.95
Soluble carbohydrates,	85.44	76.54	87.20	71.50	44.83	14.35	22.79
Albuminoids,	5.95	5.38	6 71	None.	9.63	9.75	7 92
Cellulose, gum, etc.,	......	......	......	......	0.44	7.09	5.24
Ash,	1.89	1.50	1.28	0.93	0.89	Undeterm.	1.59

[1] These determinations are probably higher than they should be, owing to the influence of dextrine upon the sugar determinations, but if there is an error, it is of the same amount in every case.

The analyses reveal certain striking points in connection with these Liebig's foods. The percentage of fat is extremely low, that of grape-sugar very high. In Horlick's and Mellin's there is no unconverted starch, in Hawley's 11 per cent. In Mellin's there were 5.95 per cent. albuminoids, and, in both the others, the percentage was very low; that in Horlick's, the larger, being but 6.71 per cent. Hawley's is very light-colored, less sweet than the other two, is more finely powdered, and has a smell resembling that of a cereal which has been submitted to torrefaction. The 10.97 per cent. of starch indicates either that the wheat and barley malt have undergone very partial conversion into grape sugar, or that this percentage of starch has been added in some form after the liquid products of the conversion have been evaporated to dryness.

In my first paper upon this subject (*Sixth Annual Report of the New Jersey State Board of Health*) I fell inadvertently into an error in speaking of Mellin's food. The original table (p. 206 of that article) stated that this food contained 5.95 per cent. of albuminoids, which was correct. Subsequently a second table was prepared for convenience in writing out my work, and into this table the clerical blunder was introduced of including the albuminoids, 5.95 per cent., along with the insoluble residue, 3.46 per cent., and putting down the sum, 9.41 per cent. under the latter head, and thus leaving zero for the percentage of albuminoids. This error I am very glad to correct in this place, as well as the misapprehension into which it led me, that the supposed absence of albuminoids indicated the failure to use wheat and barley-malt in the preparation of this food. On the contrary, the constitution of the food shows that both these articles were used, together with bicarbonate of potash, and the Mellin's is a genuine Liebig's food.

In fact, the percentage of albuminoids in a Liebig's food has not the same relative significance as it has in the case of Class I., or Farinaceous Foods. This point may be best explained by an examination of the analysis of Savory & Moore's Infant Food and the

Baby Sups. These are composed of the materials, out of which, by a long and tedious process of conversion, a food like Nos. 8, 9, and 10 is made. This process is as follows: Equal parts of wheat-flour and barley malt, together with a certain amount of wheat-bran added, it is said, for the sake of the adherent phosphates and nitrogenous matter, together with one per cent. of bicarbonate of potash, are mixed with sufficient water to make a thin paste. The mixture is allowed to stand at ordinary temperature for several hours, and then heated to 150°, until the conversion of the starch is completed. It is then strained, and the residue pressed and exhausted with warm water. The extract is evaporated *in vacuo*, at as low a temperature as consistent with rapidity of working, dried at a higher temperature, and, finally, by very skilful, manipulation, brought to a finely pulverulent mass, which does not contain sufficient moisture to cake together, and is a most commendable product of technical skill.

By careful selection of highly albuminous wheat and excellent barley the best results possible can be obtained. What they are, and whether or no the addition of bran increases the percentages of phosphates and other valuable constituents in the extract, I am not prepared to say. I should have very gladly complied with the wishes of manufacturers of Liebig's foods to investigate these matters for them as a matter of ordinary professional labor, but felt that my candid expressions with regard to this subject would not permit me to do so without laying myself open to the imputation of bias. But these explanations suffice to show that the percentages of albuminoids in Liebig's foods have not the same significance as in other classes of infant's foods. The starch has undergone conversion into dextrine and grape-sugar, which, being soluble, pass into the liquid extract, and are evaporated down and pass into the final product. But only that portion of the albuminous matter which is contained in particles so fine as to pass through the strainers, together with the solid albuminous matter (and this is especially valuable in the

nutrition of infants), is found in the final product. This deficiency in total albuminoids therefore is inevitable, and is an evidence of the genuineness of a Liebig's food. To determine how large a proportion of these albuminoids passes into *solution* would be of great value. To this end a mode of analysis should be used for these foods, specially designed for them, and this analysis should give not only the varieties of sugar, the dextrine, and soluble and insoluble albuminoids, but the peculiar kinds of extractive. If the virtue of Liebig's foods resides only in their not containing starch, but its products of transformation, sugar and dextrine, together with sufficient bicarbonate of potash to make the reaction of the infant food, like human milk, always alkaline, then so tedious and expensive a process would not have to be resorted to in order to obtain a mixture which can be made directly very cheaply. If, on the other hand, the other substances extracted from the grain have an important dietetic value of their own, then the analysis should be directed to ascertain their nature and amount. This has hitherto not been done, nor do we possess the records of physiological experiments bearing expressly upon these points of inquiry. In Savory and Moore's food this process of conversion has not been effected. Neither can it be when the food is prepared according to directions. These are to put one or two tablespoonfuls of the food into a suitable vessel, mix gradually, with two or three tablespoonfuls of boiling water or milk, and cool to the temperature of new milk. The conversion of the 36.36 per cent. of starch cannot be effected so readily. If it be (and it is stated that there is no objection (!) to so doing) heated until it thickens, afterwards removed from the fire and stirred until it become fluid, then a greater amount of starch will be converted than when mixed with boiling water only, but there is no certainty nor probability that, in any case, all the starch will undergo conversion. Neither its composition nor its method of preparation explain why, when this food is prepared with water, the food is equivalent to mother's food in nourishing power, and why, as the advertisement likewise claims, when prepared with milk only, it has twice the strength.

It is certainly not to the 36.36 per cent. of starch that it owes this power, nor to the 9.63 per cent. of the albuminoids of wheat and barley. In fact, this large proportion of albuminoids shows how much less of wheat and barley has actually been employed in the preparation of Savory and Moore's food, than should have been employed in order to obtain a genuine Liebig's food. For, in the latter, the fluid extract of the wheat and barley is used, and the residual matter, which is not beneficial but injurious in the nutrition of children, is strained off, so that the solid matter remaining after evaporation represents an amount of wheat and barley originally taken greatly in excess of its own weight. In Savory and Moore's food, the percentage of albuminoids is that corresponding to the sum of the weights of the ground barley malt and wheat originally taken. These are added together, along with the alkaline bicarbonate, and, when prepared for use, the insoluble albuminoids and the useless and irritating particles, which Liebig directed should be strained off, are allowed to remain in the food.

I have spoken thus severely of Savory and Moore's food, because, whilst claiming to be prepared in accordance with Liebig's principles, it actually contravenes them. The following much less ambitious preparations are worthy of more favorable comment:

Baby Sup No. 1 is advertised as an excellent substitute for mother's milk, in case of infants under four months of age. It is a very sweet, partly crushed whole oat-meal, very palatable even before cooking, and dissolving readily in the juices of the mouth. It is prepared from malted oats, and, after the conversion of the starch has gone as far as it is thought it will proceed, the oats are carefully hulled, only a residue of the coat being left in the crack of the grain. The analysis shows the lowered percentage of starch, and the increase of saccharine bodies due to this treatment.

Baby Sup No. 2 consists of wheat flour, malted barley, and bicarbonate of potash, in the proportions given in Liebig's formula. In its dry state the mixture has little taste, but becomes thin, sweet, and palatable

on cooking. The analysis gives but a partial result of this change, because the food was cooked only five minutes before the analysis, whilst the directions call for a half hour's cooking. But already much of the starch has been converted into dextrine. These foods are commendable efforts to carry Liebig's views into practice, and it is to be regretted that a certain amount of care and time is required to properly cook them, and, for this reason, they will probably have only a restricted use. In Mellin's, Horlick's, and Hawley's foods this care and time have already been expended by the manufacturer, and experience has shown that few mothers or nurses can or will take so much trouble.

Keasbey and Mattison's Foods.—From the point of view above taken, it is possible to explain a peculiarity in its composition, which I failed at first to understand. This is, that the sample of this food which I examined contained no albuminoids whatever. Its advertisement states that it is an extract prepared from malted grain, dextrine, alkaline phosphates, etc., and that it is perfectly free from starch. It does not resemble the other preparations of Liebig's foods in the market, being, unlike them, a thick liquid, resembling, both in taste and appearance, some variety of molasses or syrup. My first explanation of the entire absence of albuminoids was, that no grain was used in its preparation. This is not the case. The food is not strictly a Liebig's food, but in reality a neutralized extract of malted barley. The ground malt is extracted with hot water, the liquid strained, evaporated *in vacuo*, and neutralized with bicarbonate of potash. There is no question that the albuminoids did not pass the sieve, for I could neither determine them by ordinary methods, nor get the reaction for nitrogen by the most severe tests. But, as before stated, there must be present certain extractives, and the analysis should be directed to finding them, and thus seek to explain the undoubted benefits frequently conferred by the use of this food.

Before concluding with regard to Liebig's foods, I desire to say a few words concerning the percentages of dextrine and cane-sugar reported for these foods.

The former would be nearly that which would correspond to the difference between the amount of soluble carbohydrates and the sum total of grape-sugar and cane-sugar. But it is not put down in the analysis, because it was not directly determined, and I did not know how much soluble matter of other kinds, possibly soluble albuminoids and other extractive matter of great dietetic value, might possibly be thus erroneously set down as dextrine. The percentages of cane-sugar are not strictly correct, because the presence of dextrine somewhat raises the results obtained, and there is no method, so far as I am aware, of making a satisfactory determination of cane-sugar and grape-sugar and dextrine in a mixture of the three bodies. But the method applied was the same in every instance, so that, besides the cane-sugar proper which is derived from the cereal used, the added percentage due to the error arising from the presence of dextrine would be nearly the same in every sample analyzed. The investigation of this problem should also come into the complete analyses of these foods, as well as the other matters spoken of hitherto. Scheibler, indeed, has indicated a method of detecting dextrine when mingled with cane-sugar in an amount not exceeding 3 per cent.; but in these cases we have, as in Mellin's food, no less than 37 per cent. of dextrine, and 44.69 per cent. of grape-sugar as well, the cane-sugar itself being comparatively insignificant. His method is of no value for such cases.

Class III. Milk Foods.

	15. Nestlé.	16. Anglo-Swiss.	17. Gerber's.	18. Am'can-Swiss.
Water, . . .	4.72	6.54	6.78	5.68
Fat, ...	1.91	2.72	2.21	6.81
Grape-sugar and milk-sugar,	6.02	23.29	6.06	5.78
Cane-sugar, ...	32.93	21.40	30.50	36.43
Starch, ...	40.10	34.55	38.48	30.85
Soluble carbohydrates, .	44.88	46 43	44.76	45.35
Albuminoids, ...	8.23	10.26	9.56	10.54
Ash, ...	1.59	1.20	1.21	1.21

These articles have been prepared in order to supply a food which should contain the constituents of milk to a certain extent, and yet should be free from the objections to which condensed milk is open. The attempt was first made by H. Nestlé, in Vevey, Switzerland, but at the present time many milk factories are in existence, including one in our country at Little Falls, in New York, under the management of Dr. N. Gerber. All of these milk foods consist of cereals specially prepared in combination with milk. The preparation of the Anglo-Swiss milk food is stated to be as follows: 20 parts of Russian wheat flour and 20 parts of oatmeal are made into a dough and baked. The biscuit is then ground fine, mixed with 60 per cent. of condensed milk, dried by a slow heat at 120° to 130°, ground, and sufficient wheat gluten added to bring up the percentage of albuminoids to the same amount as that present in human milk. It is evident that apart from giving a general idea of the method of manufacture, this statement cannot be regarded as correct, inasmuch as the percentage of fat in the Anglo-Swiss milk food analyzed is much less than that which would be imparted by 60 per cent. of condensed milk, The percentage of albuminoids likewise makes it doubtful whether any albuminoids in addition to those present in the milk and flour, have been added in the form of specially prepared wheat gluten.

According to Dr. N. Gerber (*Milk Analysis*, p. 70), the various milk foods in the market vary in composition as follows:

					Average.
Water,	5.0	to	10	per cent.	7.50
Salts,	1.5	"	3	"	2.25
Fat,	4.0	"	7	"	5.50
Albumen,	9.5	to	18	per cent.	13.25
Soluble carbohydrates,	35.0	"	55	"	45.00
Insoluble "	15.0	"	35	"	25.00
Cellulose,	0.5	"	1	"	0.75

It will be noted that Nestlé's food departs further from the average than any of the other preparations, and the American-Swiss approaches most nearly. The

percentage of fat in the latter is much larger than in the other preparations, and the percentage of albuminoids is likewise the greatest. On preparing these various brands, the Nestlé, Anglo-Swiss, and Gerber's were very palatable and delicate in their flavor, more so than the American-Swiss, which had a slight rancidity connected, no doubt, with the large percentage of fat and fatty acids. Under the microscope the various milk-foods had a similar appearance, exhibiting agglomerations of starch granules and globules of milk. They all gave the starch and dextrine reaction with iodine, the reaction for dextrine being stronger in the Gerber than in the Anglo-Swiss. All had a faintly acid reaction except Nestlé's, which was slightly alkaline.

All of them have the same points in their favor—a high percentage of albuminoids, fats, and salts, this being especially true of the American-Swiss. The conversion of the starchy matters into dextrine by previous baking gives to this class of infant foods the advantages of that class of prepared cereal, which have been rendered easily assimilable by a process of previous torrefaction. The addition thereto of condensed milk has both advantages and disadvantages. The advantages are that the condensed milk is milk in a pure and safe form. Instead of being coagulated in large, cheesy masses in the child's stomach as would be liable to be the case if the condensed milk, after thinning with water, were given alone to the infant, the admixture of dextrine and torrefied flour keeps the caseine divided, and causes it to form in small flakes more nearly analogous to those forming from woman's milk. The condensed milk likewise adds a noteworthy percentage of fat, which is conspicuously absent from the other infant foods. It also adds a certain amount of milk-sugar and increases the percentage of albuminoids and valuable saline matters, more especially the phosphates. The principal disadvantage is, that condensed milk is preserved with the aid of cane-sugar, its analysis being as follows:

Water, . . .	20.0	to	30.0	per cent.
Salt, ...	1.5	"	3.0	"
Fat, ...	8.8	"	12.0	"
Albuminoids, . . .	10.0	"	13.0	"
Milk-sugar,. . . .	10.0	"	15.0	"
Cane-sugar, . . .	30.0	"	45.0	"

Cane-sugar, therefore, being relatively by far the largest constituent, there soon arrives a point in the manufacture of milk food when the addition of condensed milk must cease. Otherwise the percentage of cane-sugar, which like other carbohydrates is very objectionable when it takes the place of a proper amount of albuminoids, would become excessive, and indigestion thereby be induced in the infant using such food. The remedy, it appears to me, would be found by using a condensed milk preserved without the aid of cane-sugar, and since this can now be successfully effected by means of Appert's method, the preparation of a milk food not open to the above objection should be soon satisfactorily accomplished. In that case we should have an infant's food with a very high percentage of albuminoids, fats, and salts; and a low percentage of carbohydrates. The sugar would be present in the form of milk-sugar derived from the milk, and as grape-sugar derived by a process of torrefaction from the meal. The last in its turn would not have to be present in larger amounts than what are requisite to supply the starch and dextrine, which are of use to prevent coagulation of the caseine in large masses.

Condensed and Preserved Milk.

	Condensed (mean of 41).	Condensed (diluted).	Preserved Alpine.	Preserved Amer.-Swiss.	Preserved Am.-Swiss (diluted).
Water, . .	30.34	88.39	58.57	59.21	87.78
Fat, . . .	12.10	2.82	13.21	11.55	3.46
Milk-sugar,	16.62	2.77	15.29	13.04	3.91
Cane-sugar,	22.26	37.1			
Albuminoids,	16.07	2.68	11.36	14.10	4.23
Ash, . . .	2.61	0.43	1.78	2.09	0.62

It will be seen that when the condensed milk is diluted until its percentage of water is about the same

as in human milk, it has relatively too little fat and too little sugar (the larger portion of that also being cane-sugar) as compared with human milk. It has also too much albuminoids and ash.

Preserved milk is the result of scientific investigation applied to this subject, and its manufacture marks a great advance in the technique of the milk industry. The product, when diluted, has no cane-sugar (an abnormal constituent of milk), and the ratio of its constituents is similar to ordinary cow's milk. It differs, of course, from human milk, and requires the addition of milk-sugar, fat, and of some bland inert attenuant, like torrefied wheat or barley-flour, to overcome the general objection to any form of cow's milk as a substitute for woman's. Experiments in this direction are on foot, and will probably result in supplying a milk food not open to some of the objections urged against previous preparations of this class. The keeping qualities of the preserved milk are likewise very remarkable; its introduction is a great public boon, and cannot fail to exert a powerful influence upon the future of urban milk-supply, and the alimentation of infants.

Conclusions.—I have been frequently asked why I do not publish my own opinion as to the best of the various foods now in use. To do so would be very unwise for many reasons. But I have endeavored to do what I have regarded as of far more importance than this, which is to praise or blame just as the information afforded by physical and microscopic examinations and chemical analysis demanded, without partiality or bias, and seek out and state the principles upon which, as it appeared to me, the dietetic value of these articles of infant food depended.

To summarize the points which I have endeavored to establish:

1. Cow's is in no sense a substitute for woman's milk.

2. Attenuation with water alone is inadequate, and chemical metamorphosis, or, mechanically, the addition of some inert attenuant is required, in order to permit of the ready digestibility of cow's milk by infants.

2. The utility of manufactured infant's food is to act as such attenuants, and as such they take the place of the simple barley and oatmeal water, the sugar, cream, baked cracker, arrowroot, etc., etc., used in former times.

4. The results of both chemical and physiological analysis are opposed to any but a sparing use of preparations containing large percentages of starch.

5. It is eminently probable that besides acting as attenuants, the matters extracted in the preparation of barley and oatmeal water, and still more the soluble albuminoid extractives obtained at ordinary temperatures (whereby coagulation is prevented), by Liebig's process, have a great independent value of their own. For this reason, instead of employing starch, gum, gelatine, sugar, etc., the use of a natural cereal extractive, containing saccharine and gummy matters and soluble albuminoids as well, such as our great and inspired teacher Liebig himself advocated, is in accordance with the developments of science since his time.

6. The use of a food made up of equal parts of milk, cream, lime-water, and weak arrowroot water, as practised for years by the late Dr. J. Forsyth Meigs, and recently advocated by his son, Dr. Arthur V. Meigs, is sustained by theory, analysis, and practice. It provides for the increase of fat to an amount comparable to that contained in human milk. It adds alkali to permanent reaction, and to convert caseine into soluble albuminates. It adds a little bland attenuant. And if, in addition, the amount of milk-sugar were raised, and instead of arrowroot water, barley or oatmeal water were substituted, as the case demanded, it would approach, it appears to me, still more nearly to the conditions required.

7. The perfect solution of the present problem is to be found in the modification of cow's milk by chemical processes, so as to make it physiologically equivalent to human milk. The nature of these processes and the results to be obtained, are at present so nearly wrought out, that there is good ground for believing that such a solution of this problem is not far distant in the future.